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# DEVICE FOR CONTAINING NUCLEI OF LIGHT ATOMS IN A SOLID PHASE

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| References to Other Related National Documents: | |

# DEVICE FOR CONTAINING NUCLEI OF LIGHT ATOMS IN A SOLID PHASE

[Dispositif permettant de confiner dans une phase solide des noyaux d'atomes légers]

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The present invention relates to a device which allows /1* the confinement of nuclei of isotopes of hydrogen, helium or

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*[Numbers in the margin indicate pagination in the foreign text.]

other light elements (lithium, beryllium, boron) in a solid phase so as to increase the probability of their interacting.

a) State of the art

It is known how to fuse the nuclei of light atoms, for example deuterium or tritium, by accelerating them by means of a difference in potential and by projecting them one against the other so that their relative speed allows overcoming the repulsion due to the positive charges which they carry. (Optimum of acceleration at approximately 100 kiloelectron Volts for the DT reaction.) It is also possible to fuse them by heating them at high temperature, in which case the thermal agitation allows overcoming the repulsion of the nuclei.

It is also possible to obtain a reaction of fusion by bringing the nuclei close to each other without however imparting sufficient energy to them so that they come in contact: Thus by creating molecular ions of deuterium (ion where the electron which binds the two nuclei of deuterium is replaced by a mu meson or "muon") the nuclei are brought close to each other approximately 200 times. A quantum mechanism, the tunnel effect, then allows fusion of the nuclei. (In $10^{-11}$-$10^{-13}$ seconds.)

This tunnel effect even occurs in normal molecules of deuterium, however the "spontaneous fusions" which result are infinitely less probable ($3 \times 10^{-64}$ fusions per molecule and per second according to the calculations of Koonin and Nauenberg published in Nature, Vol. 339, pp. 690-691, 1989). For example, Jupiter and Saturn radiate into space twice the quantity of

energy which reaches them from the sun. This excess of energy is thought to be due to spontaneous fusion of the isotopes of hydrogen and of helium in a metal phase created by the pressure in the core of these celestial bodies.

It should be noted that the probability of fusion as a /2 result of the tunnel effect varies enormously with the distance between the nuclei. A small variation in their distance can result in an enormous increase in the fusion rate. There have been publications indicating that it is possible to increase this fusion rate by charging an electrode made of palladium by simple electrolysis of heavy water (Fleismann [sic; Fleischmann] and Pons, J. Electroanalyt. Chem., 261, pp. 308-308 (1989); Jones et al., Nature, 338, pp. 737-740, 1989). However, the results obtained are at the limit of detection of the instruments and they have not been confirmed by all the teams which have tried to reproduce them.

b) Description

The present invention is based on the combination of two known physical principles:

1) The capacity which atoms of hydrogen and its isotopes have, and probably the isotopes of helium and lithium as well, of inserting themselves in the crystalline matrix of palladium, and of titanium.

These elements are present in the crystalline matrix in the form of ions, the lost electrons being shared with the metallic phase. As long as the concentration of light ions does not exceed certain limits, the steric hindrance stabilizes the

ionized state in comparison to the atomic or molecular state, the latter deforming the matrix as a result of its larger size. This is the case even if the ionization potential of the light element is such that the state of the positive ion is the energy state which is the most unstable from a chemical point of view. Example: The ion $D^+$ is stabilized in comparison to the molecule $D_2$ or to the deuteriide $D^-$, both being of larger size. The ions with low molecular weight can circulate in the matrix, due to the effect of the thermal agitation or of an electrical field. Thus, it has been demonstrated that it was possible to charge a metal with deuterium atoms by electrolysis of a solution containing heavy water.

2) The enormous electrical field existing in the zone of junction of a semiconductor diode.

The method which is the subject-matter of the present description consists in forming a metal/semiconductor junction which has the property of a diode, allowing the passage of current in only one direction, by associating in close contact: /3

a) An electrode of palladium or of other heavy metal containing atoms of isotopes of hydrogen, helium or of lithium. The step of introduction of the light ions occurs either by ionic implantation, by heating in an alloy of lithium or in an atmosphere of isotopes of hydrogen or of helium, by the generation of an electrical discharge in a rarefied atmosphere containing these same gases or by the electrolysis of a solution containing such isotopes.

b) A p-type semiconductor electrode, that is an electrode made of a semiconductor where the transports of charge occur by

migrations of electron-holes. Usually, these carriers of virtual charges are called "holes." In such semiconductors, the electronic conduction plays a small role or none at all. This semiconductor can be of the intrinsic or extrinsic type, that is it may owe its properties to the addition of a small proportion of "doping" elements such as boron.

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This association of a metal such as palladium and a semiconductor such as silicon form the diode. It conducts the current in only one direction. In the opposite direction, the flow of the current is blocked, the difference in potential being located in the zone of contact between the two materials: the junction. It is this reverse mode which is used in the device described here. At the time of application of voltage, the positive ions will migrate in the crystalline matrix of the palladium and they will reach the junction. They will accumulate there, because their size does not allow them to penetrate into the crystalline matrix of the silicon. They will also settle there due to the effect of the enormous electrical field which exists in the junction zone (Figure 1).

The thickness of the latter zone is a few microns, and /4
the [potential of] the field reaches several millions of volts per meter for a voltage at the terminals of the diode of only a few volts. It is difficult to calculate the density of light ions which will result in the vicinity of the junction, but one is nevertheless justified in assuming that it is considerably larger than what is observed, for example, in solid deuterium or solid lithium or even in palladium deuteriide. The probability of an interaction of light ions as a result of the tunnel effect

is therefore considerably increased; this pertains particularly to the nuclear fusion reactions. These reactions are detected by the release of heat and possibly neutrons. The calorimetric studies are facilitated because the diode in itself gives rise to only a small release of heat as a result of the Joule effect due to the leakage current which can be made very low by an appropriate construction.

The reactions facilitated by this device include the following reactions:

$$D+D \longrightarrow {}^{3}T+p + 4\ Mev$$

$$D+D \longrightarrow {}^{4}He+n + 3{,}27\ Mev$$

$$D+D \longrightarrow {}^{4}He+\gamma + 23{,}85\ Mev$$

$$D+D \longrightarrow {}^{4}He + e^{-} + 23{,}85\ Mev$$

(internal conversion)

In theory, in a crystalline matrix, it is possible to have a conversion of energy of the Mossbauer type: The fusion energy is converted directly into vibration of the crystalline matrix, that is into heat:

$$D+D \longrightarrow {}^{4}He + 23{,}85\ Mev$$

In this case no neutrons are observed.

$$D + T \longrightarrow {}^{4}_{2}He + n + 17{,}58\ Mev$$

$$D + {}^{3}_{2}He \longrightarrow {}^{4}_{2}He + p + 18{,}34\ Mev$$

/5

$$D + {}^{5}_{3}Li \longrightarrow {}^{4}_{2}He + {}^{3}_{2}He + 2p + 2{,}8\ Mev$$

$$p + D \longrightarrow {}^{3}_{2}He + \gamma + 5{,}5\ Mev$$

$$D + {}^{6}_{3}Li \longrightarrow 2\,{}^{4}_{2}He + 22{,}4\ Mev$$

$$p + {}^{7}_{3}Li \longrightarrow 2\,{}^{4}_{2}He + 17{,}35\ Mev$$

$$p + {}^{11}_{5}B \longrightarrow {}^{4}_{2}He + {}^{4}_{4}Be + 8{,}6\ Mev$$

$$p + {}^{3}_{2}He \longrightarrow {}^{4}_{2}He$$

General principles of construction of palladium/semiconductor junctions /6

In the following paragraphs, the term "deuterium" will also designate the other isotopes of hydrogen as well as the isotopes of helium, lithium and beryllium.

The term "silicon" will also designate any semiconductor with equivalent properties (that is of p-type conductivity where the conduction s' occurs by migration of electron-holes) such as

gallium arsenide, germanium, copper sulfide, lead sulfide, zinc sulfide, copper oxide, lead oxide, zinc oxide, palladium sulfide, etc...

The junction between the deuterium-doped palladium and the p-type semiconductor according to the principle described above can be constructed in different ways:

1) By the contact of a deuterium-doped metal tip and a silicon plate or plate of p-type semiconductor with equivalent properties.

2) By contact between a palladium plate or metal plate with equivalent properties, that is one whose crystalline matrix permits the intercalation and the migration of the deuterium ions and a silicon plate. The palladium plate is first doped with deuterium using the techniques described below.

3) By atomization under a vacuum [sic; "vacuum deposition"] of palladium onto the silicon. In this case, the doping of the palladium with deuterium can occur during the operation of the device, the latter being immersed in heavy water. During the operation, the deuterium penetrates into the palladium layer, passes through it and accumulates at the palladium/silicon junction.

This disposition being the most effective one, it will be detailed further below.

4) By deposition of molten silicon onto palladium doped with deuterium.

5) By deposition of amorphous silicon onto the palladium /7 doped with deuterium by decomposition of a silicon compound in gaseous phase.

6) By deposition of silicon by thermal atomization under a vacuum onto the palladium doped with deuterium.

7) By successive depositions under a vacuum of palladium, doping of the metallic layer with deuterium by electrolysis of heavy water or electrical discharge under a reduced pressure in an atmosphere of deuterium, followed by deposition of amorphous silicon by atomization under a vacuum or gaseous phase deposition.

This manner of proceeding leads to the formation of stacks of junctions leading to operation at a higher total polarization voltage and thus to an increase in the efficacy and in the number of reactions between the deuterium ions.

8) By electrolysis of a solution of a palladium salt in heavy water using a negative electrode made of silicon.

Electrical voltage applied to the terminals of the fusion diode /8

It is possible to apply a DC voltage to the terminals of the diode constructed according to the methods described above.

The DC voltage plays a dual function:

1) It causes the migration of the ions in the interior of the palladium to the junction where they are stopped.

2) It confines the ions in the zone of the junction with strong electrical field and it compresses them one against the other, considerably increasing the probability of their reacting as a result of the tunnel effect.

It will be advantageous to use a voltage which is as close as possible to the "breakdown" voltage of the rectification

junction constructed. In this way, the electrical field is as strong as possible. Beyond this voltage, there is the risk of destroying the junction.

However, a semiconductor diode can support transient voltages which are higher than the limit voltage without being irreversibly destroyed. One can thus use pulsed voltages overlaid on the DC bias voltage of the diode. The DC voltage causes the migration of the ions towards the junction, and the higher voltage pulses abruptly compress the ions and force them to fuse.

The duration of the pulses and their voltage will be determined in such a manner that the junction does not suffer an irreversible modification of its properties.

Figure 2 gives an idea of the oscilloscopic recording of such a pulsed voltage.

In the case of the use of a pulsed voltage, the fusion reactions also take place in a pulsed manner, as does the possible resulting release of neutrons. This may present advantages, for example in neutron radiography [unconfirmed translation] or the diffraction of neutrons by dynamic structures (biochemical studies).

c) Detail of the construction of a fusion diode /9

The most effective and most practical method seems to be atomization under a vacuum of palladium onto a plate of silicon.

One can use as substrate wafers of monocrystalline silicon ingots used in microelectronics and for the construction of photocells.

This is the solution which we use for the prototype. One can also use wafers of polycrystalline silicon, depositions of polycrystalline silicon onto an appropriate substrate (graphite, amorphous carbon, retort coal, carbon fiber, carbon ribbon, deposition of pyrolytic carbon on metal, etc...).

One can also use the silicon obtained by decomposition of a gaseous silicon compound onto an appropriate substrate.

The palladium is vaporized on silicon in an advanced vacuum by heating a few decigrams of metal in a graphite gutter raised to high temperature by the application of an electrical current. The appropriately doped silicon plates are placed at approximately 5 centimeters from the vaporization device so constructed. They are covered with a mirroring film of palladium. The adhesion of this deposit depends on the quality of the vacuum and the cleanliness of the silicon. To improve the quality of the vacuum, one can vaporize filaments of a magnesium getter which will adsorb the residual gases. Care should be taken to avoid any deposition of magnesium onto the plates of silicon by isolating the vaporization compartment of the getter from magnesium by means of screens or baffles.

The vacuum will then be broken by the introduction of deuterium. It is possible to heat the plates of silicon on an electrical heater (in an atmosphere of deuterium); this has /10 two effects:

- to stabilize the deposition of palladium and increase of the size of the microcrystals (recooked)
- to start causing the penetration of deuterium into the crystalline matrix of the metal.

A layer of polymerizable resin will be deposited on the opposite side of the silicon plate (which carries the electrical connection) by immersing the latter in the still liquid resin. The resin will be caused to overflow slightly to protect the wafer (Figures 3 and 4).

After completion of the polymerization, the semiconductor diode so obtained will be immersed in heavy water, possibly tritiated heavy water.

It [the diode] will constitute the negative electrode of an electrolysis cell, the other electrode (made of platinum) being connected to the positive pole of a generator. One can add a few drops of hydrazine or hydroquinone to the heavy water to avoid the possible oxidation of the palladium.

The tritiated heavy water can be gelled with an appropriate polymer (agar, acrylamide).

The conductivity of water is maintained if necessary at the most appropriate value using a neutral or slightly acidic salt (for example a lithium salt).

The $D^+$ and $T^+$ ions present in the solution penetrate into the layer of palladium, migrating in the crystalline matrix, and reach the zone of junction where they accumulate. The probability of fusion between these ions increases as mentioned above.

Such fusion diodes prepared from plates of silicon can be connected in series. A practical arrangement is obtained by stacking these plates on top of each other with intercalation between them of a gel or a textile soaked in heavy water. The resulting device is reminiscent of the old Volta cells. The

first cell is connected to the negative terminal of a generator, the last one being placed against a positive platinum electrode. The assembly can be placed in a plastic tube and isolated by /11 pitch or a polymer poured into the interstices between the wall of the tube (figure). One can use a voltage which is higher than the voltage used with a single cell. However, such a device can be used only for a limited time period, to limit the heating which would destroy the gels and cause a short circuit or the evaporation of the electrolyte.

A conducting ceramic or a clay soaked with heavy water can be used as electrolyte and thus would allow working at a higher temperature. One could possibly work under pressure and in a supercritical state.

It is also possible to form stacks of such palladium/silicon junctions by deposition under a vacuum:

Onto an appropriate conducting substrate a layer of amorphous silicon is first deposited by decomposition of gaseous silane or atomization under a vacuum, and then this layer is doped by the addition of boron, and then a layer of palladium is deposited. This layer is saturated with deuterium or tritium or isotopes of helium by one of the means listed above, and then the cycle is again started with the deposition of a new layer of silicon and so on ...

In this manner a stack of junctions is obtained, which can operate until all the light isotopes contained in the layer of palladium are used up.

In a small volume one thus obtains an optimized device which resists heating fairly well. However, it is indispensable to provide forced cooling (circulation of water or ventilation).

The resulting fusion reaction can generate charged /12
particles: conversion electrons or protons produced by the reactions:

D+D → helium3 + P

D + helium3 → helium4 + P

2xhelium3 → helium4 + 2P

It is important to note that if a dyssymmetry is successfully introduced in the direction of emissions of these charged particles (for example by a powerful magnetic field perpendicular to the junction or the electrical field of the junction itself) it will be possible to obtain a self-sustaining difference in potential.

(If there is an excess of protons directed to the side of the palladium)

A difference in potential also appears as a result of a "photovoltaic" effect due to the intense ionization maintained in the vicinity of the junction by the protons, the rapid nuclei, the conversion electrons and the various forms of radiation emitted during the fusion reactions. It is difficult to say in advance whether the difference would be sufficient to maintain the reaction and at the same time produce a surplus of directly usable electric energy but, although this is hypothetical, there is a theoretical possibility and it should be mentioned in the present description. In such a case, only the "startup" of the device would require an external voltage.

The reaction is stopped by short-circuiting the electrodes.

In any case, a dyssymmetry in the emission of the neutrons can be created simply by placing on one side of the device a plastic screen for decelerating and an absorbent screen of boron

or cadmium. The rapid neutrons continue to be emitted in the opposite direction and will thus create a force, albeit a weak one, which can be maintained over long periods of time and which can be used for the propulsion of space vehicles.

Legend to the figures /13

Figure 1: Distribution of the electrical field in a diode with palladium/silicon junction.

1: Positive electrode made of platinum
2: Layer of palladium
3: Palladium/silicon junction
4: Heavy water
5: Silicon plate

Figure 2: Pulsed voltage applied to the terminals of the device.

Abscissa: Time
Ordinate: Voltage
p: DC bias voltage
t: Pulse with higher voltage

Figure 3: Fusion diode made from a wafer of silicon. (Perspective view)

1: Connection of the positive electrode made of platinum
2: Positive electrode made of platinum
3: Layer of palladium on the silicon
4: Layer of polymer insulating the wafer and the back of the device
5: Electrical connection of the silicon wafer

Figure 4: Cross section through the device along ab.

6: Wafer of silicon

7: Weld of the connection to the negative terminal of a generator

Claims /14

1. Device intended for confining in a solid phase the nuclei of isotopes of hydrogen, helium, lithium, beryllium or boron to increase their probability of fusion, characterized in that it consists of a diode with junction formed by the contact between an electrode made of palladium or titanium containing atoms of the isotopes cited above and an electrode made of silicon or of a p-type semiconductor with equivalent properties such as gallium arsenide, germanium, copper sulfide, copper oxide, lead sulfide, lead oxide, zinc oxide, palladium sulfide.

2. Device according to Claim 1, characterized in that the junction zone between the palladium (or the titanium) and the silicon (or the semiconductor) is subjected to an intense magnetic field with the same direction as the electrical field which passes through it.

3. Device according to Claim 1, characterized in that it is constructed by deposition of palladium by thermal atomization under a vacuum or by electrolysis on a wafer of silicon crystal.

4. Device according to Claims 1 and 3, characterized in that the introduction of the atoms of light elements occurs during operation by the electrolysis of a solution containing these elements (for example heavy water), the negative electrode consisting of the device according to Claim 3.

5. Device according to Claim 1, characterized in that it consists of a compact stack of diodes constructed by successive depositions of palladium under a vacuum, which [stack] is then doped with light elements, and then covered with silicon by the deposition of a gaseous silicon compound under reduced pressure, where this sequence of operations is repeated several times.

6. Device according to Claims 1, 2, 3, 4, 5, characterized in that it is supplied with electrical power by a DC voltage of 1/10th V to several tens of volts with superimposition of a /15 pulsed voltage with higher voltage.

7. Application of the device according to Claims 1, 2, 3, 4, 5, 6 to the production of neutrons.

8. Application of the device according to Claims 1, 2, 3, 4, 5, 6 to the production of heat.

9. Application of the device according to Claims 1, 2, 3, 4, 5, 6 to the production of electricity.

10. Application of the device according to Claims 1, 2, 3, 4, 5, 6 to the propulsion of space vehicles.

Fig.1

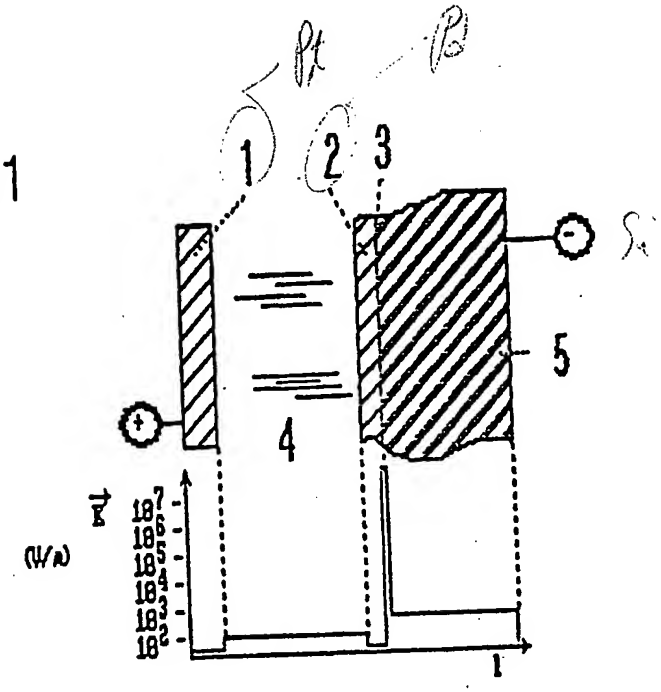


Fig.2

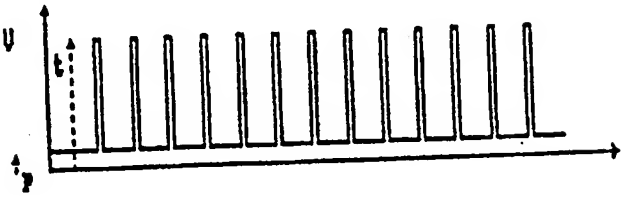

Fig.3

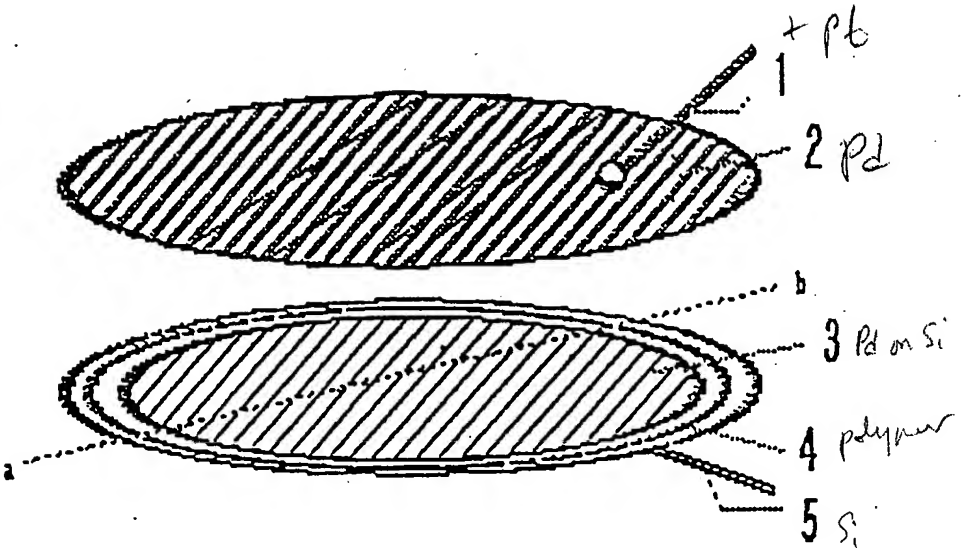


Fig.4 Coupe selon ab

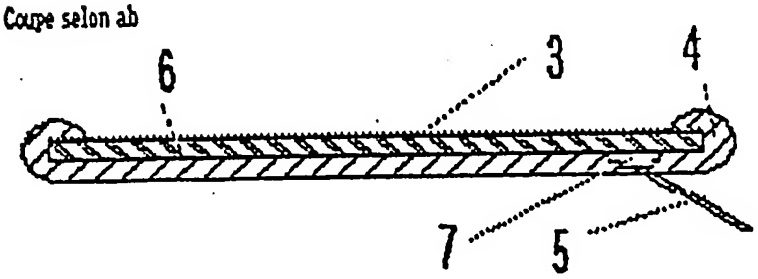


Figure 4. Cross section along ab

FRENCH REPUBLIC
National Institute
of Industrial Property

Application Number

# SEARCH REPORT

established on the basis of the most recent claims filed before the start of the search

| DOCUMENTS CONSIDERED TO BE RELEVANT | | Claims concerned in the examined document |
|---|---|---|
| Category | Citation of document with indication where appropriate, of relevant passages | |
| A | FUSION TECHNOLOGY.<br>vol. 16, no. 2, September 1989, LAGRANGE PARK, ILLIN<br>pages 240 - 242; Prelas:<br>"ADVANCED ENERGY CONVERSION METHODS FOR COLD FUSION"<br>* Entire document * | 1, 7-9 |
| D,A | NATURE.<br>vol. 338, 27 April 1989, LONDON GB<br>pages 737 - 740; JONES ET AL:<br>"OBSERVATION OF COLD NUCLEAR FUSION IN CONDENSED MATTER"<br>* Pages 737-738; Figure 1 * | 1 - |
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TECHNICAL FIELDS SEARCHED (Int Cl5)

G21B

| Date of completion of the search | Examiner |
|---|---|
| February 6, 1991 | ERRANI C. |

## CATEGORY OF CITED DOCUMENTS

X: Particularly relevant if taken alone.
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